# Chemical Process Design / Diseño de Procesos Químicos

## Topic 5.1. Equipment sizing and costing. Introduction

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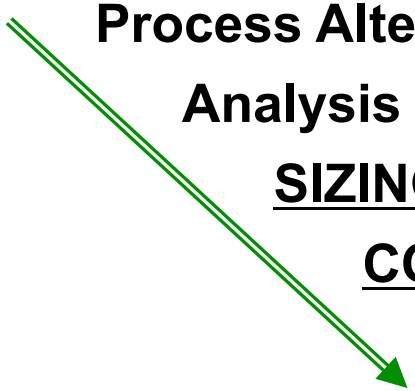
# 1.- Introduction



**Process Alternatives Synthesis (candidate flowsheet).**

**Analysis (Preliminary mass and energy balances).**

**SIZING (Sizes and capacities).**

**COST ESTIMATION (Capital and operation).**

**Economic Analysis (economic criteria).**

## SIZING

**Calculation of all physical attributes that allow a unique costing of this unit:**

- **Capacity, Height.**
- **Cross-sectional area.**
- **Pressure rating.**
- **Materials of construction.**

**Shortcut, approximate calculations (correlations) → Quick obtaining of sizing parameters → Order of magnitude estimated parameters.**

## COST

- **Total Capital Investment or Capital Cost: Function of the process equipment → The sized equipment will be costed.**
  *** Approximate methods to estimate costs.**
- **Manufacturing Cost: Function of process equipment and utility charges.**

# Categories of total capital cost estimates

## Based on accuracy of the estimate

| ESTIMATE | BASED ON | Error (%) | Obtaining | USED FOR |
|---|---|---|---|---|
| ORDER OF MAGNITUDE (Ratio estimate) | Method of Hill, 1956. Production rate and PFD with compressors, reactors and separation equipment. Based on similar plants. | 40 – 50 | Very fast | Profitability analysis |
| STUDY | Overall Factor Method of Lang, 1947. Mass & energy balance and equipment sizing. | 25 – 40 | Fast | Preliminary design |
| PRELIMINARY | Individual Factors Method of Guthrie, 1969, 1974. Mass & energy balance, equipment sizing, construction materials and P&ID. Enough data to budget estimation. | 15 – 25 | Medium | Budget approval |
| DEFINITIVE | Full data but before drawings and specifications. | 10 – 15 | Slow | Construction control |
| DETAILED | Detailed Engineering. | 5 – 10 | Very slow | Turnkey contract |

# Cost Estimation Method of Guthrie

- **Equipment purchase cost: Graphs and/or equations.**

  **Based on a power law expression: Williams Law C = BC = Co (S/So)$^{\alpha}$ →**
  **→ Economy of Scale (incremental cost C, decrease with larger capacities S, due to the value of $\alpha$ < 1).**

- **Installation: Module Factor, MF, affected by BC, taking into account labor, piping instruments, accessories, etc.**

  **Typical Values 1 < MF < 4.23.**

  **Installation = (BC)(MF) – BC = BC(MF – 1)**

- **For special materials, high pressures and special designs beyond base capacities (So) and costs (Co), the Materials and Pressure correction Factors, MPF, are defined.**

  **Uninstalled Cost = (BC)(MPF)  Total Installed Cost = BC (MPF + MF – 1)**

# Materials and Pressure correction Factors: MPF

**Empirical factors that modified BC and evaluate particular instances of equipment beyond a basic configuration: Uninstalled Cost = (BC x MPF).**

**MPF = $\phi$ ($F_d$, $F_m$, $F_p$, Fo, $F_t$)**

- $F_d$: Design variation.
- $F_p$: Pressure variation.
- $F_t$: Mechanical refrigeration factor.
- $F_m$: Construction material variation.
- $F_o$: Operating Limits ($\phi$ of T, P).
- $\phi$ (T evaporator).

| EQUIPMENT | MPF |
|---|---|
| Pressure Vessels | $F_m \cdot F_p$ |
| Heat Exchangers | $F_m (F_p + F_d)$ |
| Furnaces, direct fired heaters, Tray stacks | $F_m + F_p + F_d$ |
| Centrifugal pumps | $F_m \cdot F_o$ |
| Compressors | $F_d$ |

**To obtain the *COST (C)* of the equipment → Need S (Sizing) and MPF (Operation Conditions) → required the flowsheet mass and energy balance (Flow, T, P, Q).**

# Cost Estimation Method of Guthrie

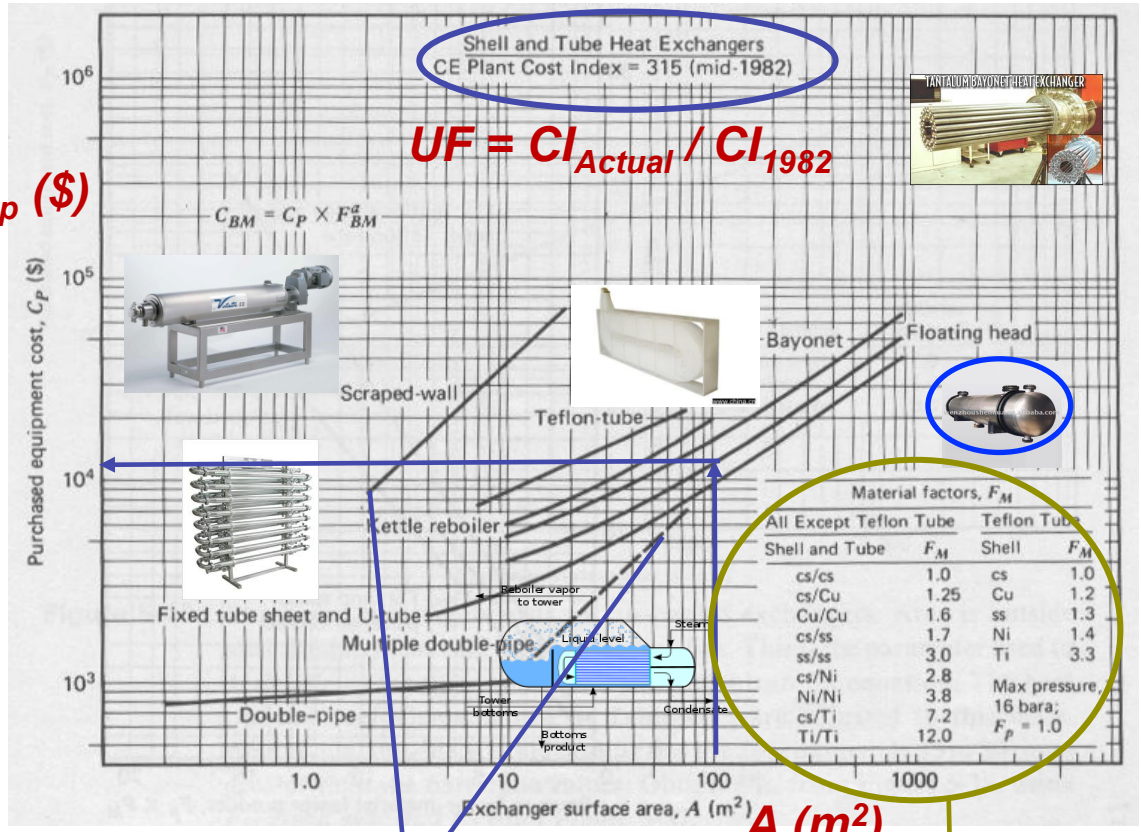
- To update cost from mid-1968 (Co and So), an Update Factor UF, to account for inflation, is applied.

  UF: Present Cost Index / Base Cost index.

**Updated bare (simple) module cost: BMC = UF(BC) (MPF + MF – 1)**

# An example of Cost Estimation: Shell and Tube Heat Exchangers

*Equipment purchase price $C_p$*




$C_p$ ($)

$UF = CI_{Actual} / CI_{1982}$

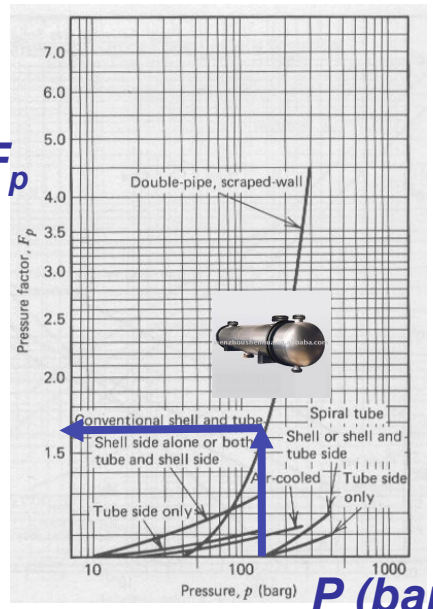
$A$ (m$^2$)

*Design Factor*

$F_d$

*Material Factor*

$F_m$

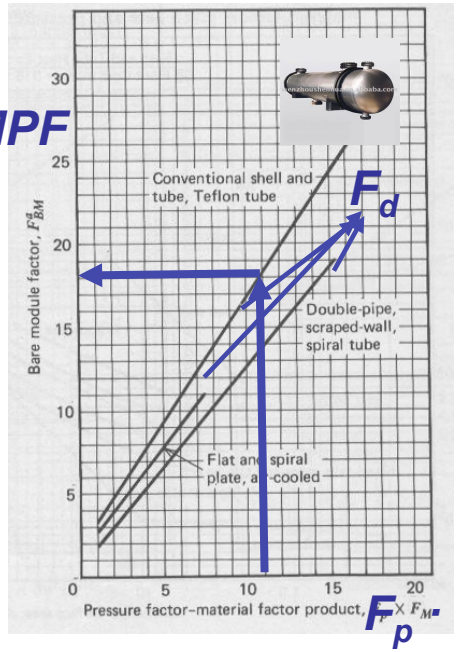



$F_p$

*Pressure Factor*

$F_p$

$P$ (bar)




$MPF$

$F_d$

*Materials and Pressure Factor (MPF)*

$F_p \cdot F_m$

$$\text{Total Cost} = UF \cdot C_p \cdot MPF$$